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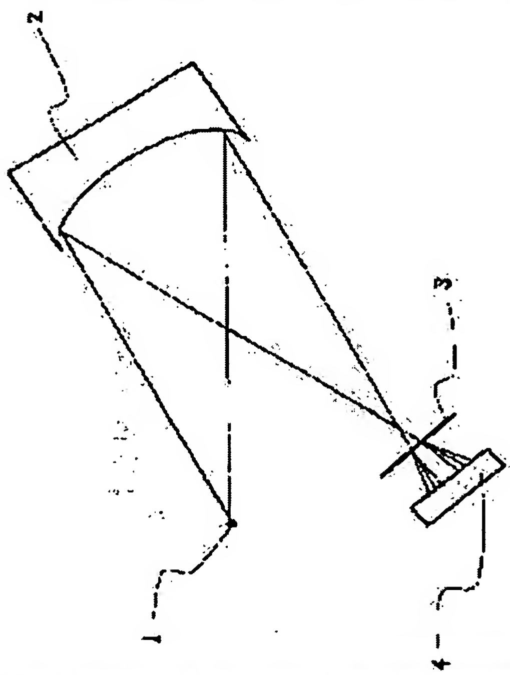
(54) MULTILAYER REFLECTION MIRROR AND EUV EXPOSURING DEVICE



(57)Abstract:
PROBLEM TO BE SOLVED: To accurately obtain necessary quantities with a measuring method for the shape of reflection wave front by removing only necessary quantity of multilayer film surface for specifically shaping the reflection surface of a multilayer reflection mirror.
SOLUTION: The wavelength of light used in the measurement is set to be that practically used by introducing in the multilayer film reflection mirror. Using a diffraction element in a measurement system as an optical element performs the measurement.

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CLAIMS
[Claim(s)]
[Claim 1] Carry out the laminating of two kinds of matter with which refractive indexes differ to a reflector by predetermined cycle length by turns, and multilayers are formed in it. In order to amend the phase of a reflected wave side, are the manufacture approach of a multilayers reflecting mirror of removing multilayers from a front face in the unit of every an about one-layer pair, and a reflected wave side configuration is measured on the operating wavelength of a multilayers reflecting mirror. The manufacture approach of the multilayers reflecting mirror characterized by computing the amount of removal in each location within a reflector from the measurement result.
[Claim 2] Are the manufacture approach of the multilayers reflecting mirror built into soft-X-ray optical system, and carry out the laminating of two kinds of matter with which refractive indexes differ to a reflector by predetermined cycle length by turns, and multilayers are formed in it. in the manufacture approach of a multilayers reflecting mirror of removing multilayers from a front face in the unit of every an about one-layer pair, where a multilayers reflecting mirror is built into this optical system in order to amend the phase of a reflected wave side The manufacture approach of the multilayers reflecting mirror which measures the transmitted wave side configuration of optical system with operating wavelength, and is characterized by computing the amount of removal in each location within a reflector of a multilayers reflecting mirror from the measurement result.
[Claim 3] The manufacture approach of the multilayers reflecting mirror which is the manufacture approach of a multilayers reflecting mirror according to claim 1 or 2, and is characterized by measuring reflection or a transmitted wave side configuration by the approach using the optical element of a diffraction mold.
[Claim 4] The manufacture approach of the multilayers reflecting mirror which is the manufacture approach of a multilayers reflecting mirror according to claim 3, and is characterized by measuring reflection or a transmitted wave side configuration using a shearing interference method, the PDI method, a Foucault test, the Ronchi test, or the Hartmann method.
[Claim 5] Carry out the laminating of two kinds of matter with which refractive indexes differ to a reflector by predetermined cycle length by turns, and multilayers are formed in it. where it is the manufacture approach of the soft-X-ray optical system which removes multilayers from a front face in the unit of every an about one-layer pair, manufactures a multilayers reflecting mirror in order to amend the phase of a reflected wave side, and assembles these multilayers reflection of two or more and this optical system is assembled The manufacture approach of the soft-X-ray optical system which measures the transmitted wave side configuration of optical system with operating wavelength, and is characterized by computing the amount of removal in each location within a reflector of each multilayers reflecting mirror from the measurement result.
[Claim 6] The manufacture approach of the soft-X-ray optical system which is the manufacture approach of soft-X-ray optical system according to claim 5, and is characterized by measuring a transmitted wave side configuration by the approach using the optical element of a diffraction mold.
[Claim 7] The manufacture approach of the soft-X-ray optical system which is the manufacture approach of soft-X-ray optical system according to claim 6, and is characterized by measuring a transmitted wave side configuration using a shearing interference method, the PDI method, a Foucault test, the Ronchi test, or the Hartmann method.
[Claim 8] It is the multilayers reflecting mirror characterized by being the multilayers reflecting mirror manufactured by the multilayers reflecting mirror manufacture approach indicated by claim 1 thru/or any of 4, and multilayers consisting of a layer containing molybdenum, and a layer containing silicon.
[Claim 9] The multilayers reflecting mirror characterized by being the multilayers reflecting mirror

manufactured by the multilayers reflecting mirror manufacture approach indicated by claim 1 thru/or any of 4, or a multilayers reflecting mirror according to claim 8, and said predetermined cycle length being 6nm to 12nm.
[Claim 10] Soft-X-ray optical system characterized by being constituted by claim 1 thru/or 4, claim 8, or any of 9 using the multilayers reflecting mirror of a publication.
[Claim 11] The manufacture approach of the soft-X-ray optical system which is the manufacture approach of the soft-X-ray optical system indicated by claim 5 thru/or any of 7, and is characterized by said two kinds of matter containing molybdenum and silicon.
[Claim 12] The manufacture approach of the soft-X-ray optical system characterized by being the manufacture approach of the soft-X-ray optical system indicated by claim 5 thru/or any of 7, and said predetermined cycle length being 6nm to 12nm.
[Claim 13] claim 5 thru/or any of 7 -- or the soft-X-ray aligner characterized by having the soft-X-ray optical system manufactured by claim 11 thru/or the manufacture approach given in any of 12, or soft-X-ray optical system according to claim 10.

DETAILED DESCRIPTION
[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the soft-X-ray projection aligner used for manufacture of a semiconductor device etc., and other soft-X-ray optical instruments.
[0002]
[Description of the Prior Art] In order to raise the resolution of the optical system restricted by the diffraction limitation of light with progress of detailed-izing of a semiconductor integrated circuit component in recent years, instead of the conventional ultraviolet rays, the projection lithography technique which used soft X ray with a wavelength [with wavelength shorter than this] of about 11-14nm is developed. (For example, D.Tichenor, et al., SPIE 2437 (1995) 292 reference) Those contents are the same although this technique is also recently called EUV (Extreme UltraViolet: extreme ultraviolet rays) lithography. (It is hereafter called EUV lithography.) EUV lithography is expected by the conventional optical lithography (wavelength of about 190nm or more) as a future lithography technique of having unrealizable resolution 70nm or less.
[0003] Since the refractive index of the matter is very close to 1 in this wavelength region, the conventional optical element using refraction or reflection cannot be used. The oblique incidence mirror using the total reflection by a refractive index being more slightly [than 1] small, the multilayers mirror which doubles a phase, is made to carry out the a large number superposition of the feeble reflected light in an interface, and obtains a reflection factor high as a whole are used. In the wavelength region near 13.4nm, if the Mo/Si multilayers which carried out the laminating of a molybdenum (Mo) layer and the silicon (Si) layer by turns are used, 67.5% of reflection factor can be obtained by direct incidence, and if the Mo/Be multilayers which carried out the laminating of Mo layer and the beryllium (Be) layer by turns are used, 70.2% of reflection factor can be obtained by direct incidence in the wavelength region near the wavelength of 11.3nm. (For example, C.Montcalm, Proc.SPIE, Vol.3331 (1998) P.42 reference.)
[0004] EUV lithography equipment is mainly constituted by the soft-X-ray light source, an illumination-light study system, a mask stage, image formation optical system, the wafer stage, etc. The laser plasma light source, the discharge plasma light source, synchrotron orbital radiation, etc. are used for the soft-X-ray light source. An illumination-light study system is constituted by the oblique incidence mirror which reflects in a reflector the soft X ray which carried out incidence from across, the multilayers mirror in which a reflector is formed of multilayers, the filter which makes only the soft X ray of predetermined wavelength penetrate, and is illuminated with the soft X ray of the wavelength of a request of on a photo mask. In addition, since the matter transparent in the wavelength region of soft X ray does not exist, not the mask of the conventional transparency mold but the mask of a reflective mold is used for a photo mask. Image formation of the circuit pattern formed on the photo mask is carried out on the wafer with which the photoresist was applied, and it is imprinted by the projection image formation optical system which consisted of two or more multilayers mirrors etc. at this photoresist. In addition, in order for soft X ray to be absorbed by atmospheric

air and to decrease it, the whole of the optical path is maintained by the predetermined degree of vacuum (for example, 1x10 to 5 or less Torrs).

[0005] Projection image formation optical system is constituted by two or more multilayers mirrors. Since the reflection factor of a multilayers mirror is not 100%, in order to suppress loss of the quantity of light, as for the number of sheets of a mirror, lessening as much as possible is desirable. Until now, the optical system (for example, T.Jewell and K.Thompson, USP 5,315,629, T.Jewell, USP 5,063,586 reference) which consists of four multilayers mirrors, the optical system (for example, D.Williamson, JP,9-211332,A, USP 5,815,310 reference) which consists of six multilayers mirrors are reported. Since the flux of light will go in optical system by catoptric system unlike the dioptric system to which the flux of light advances to an one direction, it is difficult for a limit [of avoiding the eclipse of the flux of light by the mirror] sake to enlarge NA. Although numerical aperture (NA) is made only by about 0.15 in four-sheet optical system, the design of optical system with still larger NA is attained in six-sheet optical system. The number of sheets of a mirror is usually even number so that a mask stage and a wafer stage can arrange on both sides of projection image formation optical system. Since such projection image formation optical system must amend the aberration of optical system with the limited number of pages, it is the ring field optical system by which the aspheric surface configuration was applied to each mirror, and aberration was amended only near the predetermined image quantity. In order to imprint the whole pattern on a photo mask on a wafer, it exposes making a mask stage and a wafer stage scan at a different rate by the scale factor of optical system.

[0006] The above projection image formation optical system of an aligner is the so-called optical system of a diffraction limitation, and unless it makes wave aberration small enough, it cannot obtain the engine performance as a design. As a standard of the allowed value of the wave aberration in the optical system of a diffraction limitation, there are criteria less than of 1/14 of operating wavelength with the mean square value (RMS) by Marechal. (M.Born and E.Wolf, Principles of Optics, 4th edition, Pergamon Press 1970, p.469 reference) This is conditions for Strehl reinforcement (ratio of the maximum of the point reinforcement between optical system and non-aberration optical system with aberration) to become 80% or more. The actual projection image formation optical system of an aligner is manufactured so that it may become aberration still lower than this.

[0007] In the EUV lithography technique in which researches and developments are done briskly now, as for exposure wavelength, the wavelength 13nm or near 11nm is mainly used. The configuration error (FE) permitted by each mirror is given by the degree type to the wave aberration (WFE) of optical system.

(Formula 1) FE=WFE/2/rootn (RMS)

n is the number of the mirrors which constitute optical system, and it divides by further 2 because a twice as many error as a configuration error rides on wave aberration, since both incident light and the reflected light are influenced of a configuration error in catoptric system, respectively. Configuration error permitted by each mirror in the optical system of a diffraction limitation after all (FE) It is given by the degree type to the number of sheets n of wavelength lambda and a mirror.

(Formula 2) FE=lambda/28/rootn (RMS)

On the wavelength of 13nm, in the case of the optical system which consisted of four mirrors, this value serves as 0.23nmRMS, and, in the case of the optical system which consisted of six mirrors, serves as 0.19nmRMS.

[0008] However, it is very difficult to manufacture the mirror of such a highly precise aspheric surface configuration, and EUV lithography has become the first easily unutilizable cause. The process tolerance of the aspheric surface attained by current is extent of 0.4 - 0.5nmRMS (C.Gwyn, Extreme Ultraviolet Lithography White Paper, EUV LLC, 1998, p17 reference), and in order to realize EUV lithography, the large improvement in the processing technique of the aspheric surface and a measurement technique is needed.

[0009] The epoch-making technique which can amend Factice's nm configuration error substantially was reported by by shaving off the front face of a multilayers mirror every further by Yamamoto recently. (M.Yamamoto, 7 th International Conference on Synchrotron Radiation Instrumentation, Berlin Germany, August 21-25, 2000, POS 2-189) It has drawing 2 and the principle is explained. it is shown in drawing 2 (a) -- as -- A and B -- the case where a pair is further removed as shown in drawing 2 (b) is considered from the front face of the multilayers which carried out the laminating of two kinds of matter by turns by the fixed

cycle length d. The optical path length of a multilayers 1-layer pair of thickness d to the beam of light which advances perpendicularly to a multilayers front face by drawing 2 (a) is given by OP=nAdA+nBdB. dA and dB express the thickness of each class and is dA+dB=d here. nA and nB -- Matter A and B -- it is each refractive index. The optical path length of the part of thickness d who removed the one layer pair of multilayers on the front face of the maximum by drawing 2 (b) is given by OP'=nd. n expresses a vacuous refractive index and is n= 1. By removing the maximum upper layer of multilayers, the optical distance to which the beam of light which passes through that progresses will change. this is optically [as having corrected the field configuration by the change substantially] equivalent -- certain ** Change (namely, change of a field configuration) of the optical path length is delta=OP'. - It is given by OP. In the wavelength region of soft X ray, since the refractive index of the matter is close to 1, delta becomes a small amount and amendment of a precise field configuration is attained by this approach.

[0010] As an example, the case where Mo/Si multilayers are used on the wavelength of 13.4nm is shown. In order to use it by direct incidence, they may be d= 6.8nm, dMo=2.3nm, and dSi=4.5nm. The refractive indexes in this wavelength are nMo=0.92 and nSi=0.998. If change of the optical path length is calculated using these numeric values, they are OP=6.6nm and OP'=6.8nm, It is set to delta= 0.2nm. Processing which removes a layer with a thickness of 6.8nm can amend the field configuration of 0.2nm. In addition, since the refractive index of Si layer is close to 1 in the case of Mo/Si multilayers, change of the optical path length is not based mainly on the existence of Mo layer, and it hardly depends for it on the existence of Si layer. Therefore, in case the layer of multilayers is removed, there is no need of controlling the thickness of Si layer correctly. In this example, processing should just stop the thickness of Si layer in the middle of those with 4.5nm, and this layer. That is, field configuration amendment of 0.2nm unit can be performed by processing precision of several nm. In addition, if the reflection factor of multilayers increases with the number of laminatings and a fixed number of layers is exceeded, it will be saturated, and it becomes fixed. If the laminating of sufficient number of layers to saturate a reflection factor beforehand is carried out, even if it removes some multilayers from a front face, change of a reflection factor will not be produced.

[0011]

[Problem(s) to be Solved by the Invention] Although this approach is very effective, it is necessary to calculate the required amount of amendments strictly beforehand. Although interferometers, such as the Fizeau mold which used the lights, such as helium-Ne laser, are widely used from the former in order to measure a field configuration to a precision, the accuracy of measurement is not necessarily enough. Moreover, if the front face of multilayers tends to be removed partially once and it is going to measure a field configuration again, since the reflected wave side configuration over the light and the reflected wave side configuration over the soft X ray of operating wavelength are not the same any longer, it cannot measure in the interferometer using the conventional light.

[0012] This invention is made in view of such a trouble, and in the technique which removes the surface layer of multilayers and amends the field configuration of a multilayers mirror, while making it possible to calculate the amount of amendment removal more correctly than before, it aims at making measurable the reflected wave side configuration after amendment.

[0013]

[Means for Solving the Problem] This invention is made in view of such a trouble, therefore this invention carries out the laminating of two kinds of matter with which refractive indexes differ in "reflector in the first place by predetermined cycle length by turns, and forms multilayers. In order to amend the phase of a reflected wave side, are the manufacture approach of a multilayers reflecting mirror of removing multilayers from a front face in the unit of every an about one-layer pair, and a reflected wave side configuration is measured on the operating wavelength of a multilayers reflecting mirror. The manufacture approach (claim 1) of the multilayers reflecting mirror characterized by computing the amount of removal in each location within a reflector from the measurement result" is offered. Thus, by measuring a field configuration using the wavelength to be used, information required for amendment of a field configuration is acquired correctly.

[0014] "The 2nd, it is the manufacture approach of the multilayers reflecting mirror built into soft-X-ray optical system. In the manufacture approach of a multilayers reflecting mirror of removing multilayers from a front face in the unit of every an about one-layer pair in order to carry out the laminating of two kinds of matter with which refractive indexes differ to a reflector by predetermined cycle length by turns, to form

multilayers in it and to amend the phase of a reflected wave side Where a multilayers reflecting mirror is built into this optical system, the transmitted wave side configuration of optical system is measured with operating wavelength, and the manufacture approach (claim 2) of the multilayers reflecting mirror characterized by computing the amount of removal in each location within a reflector of a multilayers reflecting mirror" is offered from the measurement result. Thereby, since the amount of **** amendments is calculated from the whole optical system, exact amendment can be performed quickly.

[0015] The 3rd is provided with "the manufacture approach (claim 3) of the multilayers reflecting mirror which is the manufacture approach of a multilayers reflecting mirror according to claim 1 or 2, and is characterized by measuring reflection or a transmitted wave side configuration by the approach using the optical element of a diffraction mold." Measurement of the wave-front configuration in the field which cannot use the optical element which requires wavefront splitting like a beam splitter by this is attained.

[0016] The 4th is provided with "the manufacture approach (claim 4) of the multilayers reflecting mirror which is the manufacture approach of a multilayers reflecting mirror according to claim 3, and is characterized by measuring reflection or a transmitted wave side configuration using a shearing interference method, the PDI method, a Foucault test, the Ronchi test, or the Hartmann method." Thereby, highly precise measurement is attained by the easy equipment configuration.

[0017] "The 5th, carry out the laminating of two kinds of matter with which refractive indexes differ to a reflector by predetermined cycle length by turns, and multilayers are formed in it. where it is the manufacture approach of the soft-X-ray optical system which removes multilayers from a front face in the unit of every an about one-layer pair, manufactures a multilayers reflecting mirror in order to amend the phase of a reflected wave side, and assembles these multilayers reflection of two or more and this optical system is assembled The transmitted wave side configuration of optical system is measured with operating wavelength, and the manufacture approach (claim 5) of the soft-X-ray optical system characterized by computing the amount of removal in each location within a reflector of each multilayers reflecting mirror from the measurement result" is offered. Thereby, highly precise soft-X-ray optical system is acquired.

[0018] The 6th is provided with "the manufacture approach (claim 6) of the soft-X-ray optical system which is the manufacture approach of soft-X-ray optical system according to claim 5, and is characterized by measuring a transmitted wave side configuration by the approach using the optical element of a diffraction mold."

[0019] The 7th is provided with "the manufacture approach (claim lake 7) of the soft-X-ray optical system which is the manufacture approach of soft-X-ray optical system according to claim 6, and is characterized by measuring a transmitted wave side configuration using a shearing interference method, the PDI method, a Foucault test, the Ronchi test, or the Hartmann method."

[0020] The 8th is provided with "the multilayers reflecting mirror (claim 8) which is a multilayers reflecting mirror manufactured by the multilayers reflecting mirror manufacture approach indicated by claim 1 thru/or any of 4, and is characterized by multilayers consisting of a layer containing molybdenum, and a layer containing silicon." These matter is cheap, and it excels also in endurance, and the multilayers reflecting mirror with still higher safety which it was, were cheap and were excellent is obtained.

[0021] The 9th, "the multilayers reflecting mirror characterized by being the multilayers reflecting mirror manufactured by the multilayers reflecting mirror manufacture approach indicated by claim 1 thru/or any of 4, or a multilayers reflecting mirror according to claim 8, and said predetermined cycle length being 6nm to 12nm. (Claim 9) " -- it provides. The multilayers reflecting mirror with which a wavelength field has a high reflection factor to the beam of light of a 12 to 15nm field even if an incident angle is about 45 degrees is obtained by this.

[0022] The 10th, "soft-X-ray optical system characterized by being constituted by claim 1 thru/or 4, claim 8, or any of 9 using the multilayers reflecting mirror of a publication. (Claim 10) " -- it provides.

[0023] The 11th is provided with "the manufacture approach (claim 11) of the soft-X-ray optical system which is the manufacture approach of the soft-X-ray optical system indicated by claim 5 thru/or any of 7, and is characterized by said two kinds of matter containing molybdenum and silicon."

[0024] The 12th is provided with "the manufacture approach (claim 12) of the soft-X-ray optical system characterized by being the manufacture approach of the soft-X-ray optical system indicated by claim 5 thru/or any of 7, and said predetermined cycle length being 6nm to 12nm." Thereby, the soft-X-ray optical

system excellent in resolution is acquired.

[0025] the -- 13 -- "-- a claim -- five -- or -- seven -- any -- or -- a claim -- 11 -- or -- 12 -- any -- a publication -- manufacture -- an approach -- manufacturing -- having had -- soft X ray -- optical system -- or -- being according to claim 10 -- soft X ray -- optical system -- having had -- things -- the description -- ** -- carrying out -- soft X ray -- an aligner (claim 13) -- " -- providing . Thereby, manufacture of a semiconductor device 70nm or less is attained by minimum line width.

[0026]

[Embodiment of the Invention] In this invention, a reflected wave side is measured on the operating wavelength of a multilayers reflecting mirror, and the amount of amendments is determined. Drawing 15 explains the procedure of field configuration amendment. The contour map [like] showing the two-dimensional configuration of the measured reflected wave side in drawing 15 (a) expresses. Let spacing of a contour line be the amount delta of amendments of the field configuration when removing multilayers further at this time. For example, in the case of Mo/Si multilayers of d= 6.8nm of cycle length for wavelength 13.4nm who explained by the Prior art (dMo=2.3nm, dSi=4.5nm), it is delta= 0.2nm. The cross section in AA of this contour map is shown in drawing 15 (b). According to the contour map of drawing 15 (a), the multilayers of a part with high height are removed further every. The thickness of a multilayers 1-layer pair can perform but 6.8nm of amendments of the field configuration of 0.2nm to soft X ray with a wavelength of 13.4nm by performing processing which removes this. The figure described into drawing 15 (a) shows whether the multilayers of how many layer pair in each field divided with the contour line should be removed. For example, what is necessary is just to carry out three-layer pair removal of the multilayers from a front face in the field of a Z twist where height is the highest. Thus, the cross-section configuration of the reflector after amending is shown in drawing 15 (c). The PV value of the field configuration after amendment can be decreased even in the same magnitude as delta.

[0027] As an approach of measuring a reflected wave side on operating wavelength, a shearing interference method can be used, for example. Drawing 1 is a plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror with a shearing interference method. After reflecting with the multilayers reflecting mirror 2, the beam of light which came out of the light source 1 is divided in a wave front by the transmission grating 3, and carries out incidence to the image detector 4. On the image detector 4, the zero-order light which has gone straight on, and the primary [**] diffracted light which changed the travelling direction by diffraction carry out [horizontal **], and piles up by carrying out, and these interference fringes are recorded. This interference fringe includes the information on the inclination of a field, and can compute the reflected wave side configuration of the multilayers reflecting mirror 2 by performing a reset action. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0028] as the option which measures a reflected wave side on operating wavelength -- PDI (Point Diffraction Interferometer) -- law can also be used. Drawing 4 is a plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by the PDI method. The beam of light which came out of the light source 1 is divided in a wave front by the transmission grating 3, after reflecting with the multilayers reflecting mirror 2. The PDI plate 5 is arranged in the condensing point location. As the PDI plate 5 is shown in drawing 6, the big opening 51 and the detailed pinhole 52 are formed. Among the wave fronts divided by the diffraction grating 3, the pitch of a diffraction grating 3 and spacing of a pinhole 52 and opening 51 are set up so that zero-order light may pass along a pinhole 52 and the primary diffracted light may pass along opening 51. The beam of light which passed through the pinhole 52 generates the spherical wave of non-aberration by diffraction. The beam of light which passed opening 52 is a wave front including the aberration of the reflector of the multilayers reflecting mirror 2. On the image detector 4, the interference fringe which piled up these wave fronts is observed. The reflected wave side configuration of the multilayers reflecting mirror 2 is computable from this interference fringe. Since the coherent high light source is the need, synchrotron orbital radiation, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0029] A Foucault test can also be used as an option which measures a reflected wave side on operating wavelength. Drawing 7 is a plot plan which measures the reflected wave side configuration of a multilayers

reflecting mirror by the Foucault test. After reflecting with the multilayers reflecting mirror 2, incidence of the beam of light which came out of the light source 1 is carried out to the image detector 4. Knife edge 6 is arranged in the condensing point location. The reflected wave side configuration of the multilayers reflecting mirror 2 is computable with change of the pattern which appears in the image detector 4 when moving knife edge 6 at right angles to an optical axis. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0030] The Ronchi test can also be used as an option which measures a reflected wave side on operating wavelength. Drawing 9 is a plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by the Ronchi test. After reflecting with the multilayers reflecting mirror 2, incidence of the beam of light which came out of the light source 1 is carried out to the image detector 4. Ronchi grating 7 is arranged in the condensing point location. Ronchi grating 7 is the gobo which formed two or more long and slender rectangle openings 71 as shown in drawing 11. On the image detector 4, since the striped pattern according to the aberration of optical system appears, the reflector configuration of the multilayers reflecting mirror 2 is computable by analyzing this. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0031] The Hartmann method can also be used as an option which measures a reflected wave side on operating wavelength. Drawing 12 is a plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by the Hartmann method. After reflecting with the multilayers reflecting mirror 2, incidence of the beam of light which came out of the light source 1 is carried out to the image detector 4. As shown in drawing 14, the plate 8 which formed much small openings 81 is formed just before the multilayers reflecting mirror 2. Although the flux of light corresponding to each opening 81 carries out incidence on the image detector 4, the reflected wave side configuration of the multilayers reflecting mirror 2 is computable from the location gap. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0032] As the measurement technique which improved the Hartmann method, the Shack-Hartmann method is in the measurement technique often used in the light field recently. This is the approach of arranging a micro-lens array in the pupil location of optical system instead of using the plate as for which the hole was vacant. Also in a soft-X-ray field, if a zone plate array is used, measurement of the reflected wave side configuration by such Shack-Hartmann method is also possible.

[0033] Even if it uses the above interference mensuration, when the accuracy of measurement is inadequate and it is difficult to measure the reflected wave side of a multilayers reflecting mirror on operating wavelength, the soft-X-ray optical system which used the multilayers reflecting mirror can once be assembled, and the approach of measuring the transmitted wave side of optical system on operating wavelength can be used. The direction which measures the transmitted wave side of optical system is easy in respect of the following rather than it measures the field configuration of the multilayers reflecting mirror of a simple substance. 1) Generally use the aspheric surface by soft-X-ray optical system in many cases. Measurement of the aspheric surface is more difficult than measurement of the spherical surface. Even if it is the optical system using the aspheric surface, since the transmitted wave side is a spherical wave, measurement becomes easy. 2) As shown in the formula 1, since the wave aberration allowed value WFE of optical system is larger than the allowed value FE of the configuration error of a multilayers reflecting mirror, the measurement is easy the allowed value.

[0034] From the measured transmitted wave side, the amount of amendments of the reflector configuration of each mirror is computable using optical design software. The subsequent procedure is the same as that of the case where the reflected wave side configuration of a multilayers reflecting mirror simple substance is measured. As an approach of measuring a transmitted wave side on operating wavelength, a shearing interference method can be used, for example. Drawing 3 is a plot plan which measures the transmitted wave side of soft-X-ray optical system with a shearing interference method. After the beam of light which came out of the light source 1 passes the soft-X-ray optical system 20, a wave front is divided by the transmission grating 3, and it carries out incidence to the image detector 4. On the image detector 4, the

zero-order light which has gone straight on, and the primary [**] diffracted light which changed the travelling direction by diffraction carry out [horizontal **], and piles up by carrying out, and these interference fringes are recorded. This interference fringe includes the information on the inclination of a field, and can compute the transmitted wave side configuration of the soft-X-ray optical system 20 by performing a reset action. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0035] as the option which measures a transmitted wave side on operating wavelength -- PDI (Point Diffraction Interferometer) -- law can also be used. Drawing 5 is a plot plan which measures the transmitted wave side of soft-X-ray optical system by the PDI method. After the beam of light which came out of the light source 1 passes the soft-X-ray optical system 20, a wave front is divided by the transmission grating 3. The PDI plate 5 is arranged in the condensing point location. As the PDI plate 5 is shown in drawing 6, the big opening 51 and the detailed pinhole 52 are formed. Among the wave fronts divided by the diffraction grating 3, the pitch of a diffraction grating 3 and spacing of a pinhole 52 and opening 51 are set up so that zero-order light may pass along a pinhole 52 and the primary diffracted light may pass along opening 51. The beam of light which passed through the pinhole 52 generates the spherical wave of non-aberration by diffraction. The beam of light which passed opening 52 is a wave front including the aberration of the reflector of the soft-X-ray optical system 20. On the image detector 4, the interference fringe which piled up these wave fronts is observed. The transmitted wave side configuration of the soft-X-ray optical system 20 is computable from this interference fringe. Since the coherent high light source is the need, synchrotron orbital radiation, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0036] A Foucault test can also be used as an option which measures a transmitted wave side on operating wavelength. Drawing 8 is a plot plan which measures the transmitted wave side of soft-X-ray optical system by the Foucault test. After the beam of light which came out of the light source 1 passes the soft-X-ray optical system 20, incidence of it is carried out to the image detector 4. Knife edge 6 is arranged in the condensing point location. The transmitted wave side configuration of the soft-X-ray optical system 20 is computable with change of the pattern which appears in the image detector 4 when moving knife edge 6 at right angles to an optical axis. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0037] The Ronchi test can also be used as an option which measures a transmitted wave side on operating wavelength. Drawing 10 is a plot plan which measures the transmitted wave side of soft-X-ray optical system by the Ronchi test. After the beam of light which came out of the light source 1 passes the soft-X-ray optical system 20, incidence of it is carried out to the image detector 4. Ronchi grating 7 is arranged in the condensing point location. Ronchi grating 7 is the gobo which formed two or more long and slender rectangle openings 71 as shown in drawing 11. On the image detector 4, since the striped pattern according to the aberration of optical system appears, the transmitted wave side configuration of the soft-X-ray optical system 20 is computable by analyzing this. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0038] The Hartmann method can also be used as an option which measures a transmitted wave side on operating wavelength. Drawing 13 is a plot plan which measures the transmitted wave side of soft-X-ray optical system by the Hartmann method. After the beam of light which came out of the light source 1 passes the soft-X-ray optical system 20, incidence of it is carried out to the image detector 4. As shown in drawing 14, the plate 8 which formed much small openings 81 is formed just before the multilayers reflecting mirror 2. Although the flux of light corresponding to each opening 81 carries out incidence on the image detector 4, the transmitted wave side configuration of the soft-X-ray optical system 20 is computable from the location gap. Synchrotron orbital radiation, the laser plasma light source, the discharge plasma light source, an X-ray laser, etc. can be used for the light source 1. CCD, an imaging plate, etc. which have sensibility in soft X ray can be used for the image detector 4.

[0039] As the measurement technique which improved the Hartmann method, the Shack-Hartmann

method is in the measurement technique often used in the light field recently. This is the approach of arranging a micro-lens array in the pupil location of optical system instead of using the plate as for which the hole was vacant. Also in a soft-X-ray field, if a zone plate array is used, measurement of the transmitted wave side configuration by such Shack-Hartmann method is also possible. In addition, although Mo/Si multilayers with a wavelength of 13.4nm used mainly with EUV lithography here were explained, it cannot be overemphasized that this invention is not limited to it and it can apply effectively also to other wavelength regions and other multilayers ingredients.

[0040] The example which applied example 1 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, it measured with the shearing interference method as shows the reflected wave side configuration of each mirror to drawing 1 on the wavelength of 13.4nm. The laser plasma light source was used for the light source 1. Based on this measurement result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0041] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0042] The example which applied example 2 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, it measured by the PDI method the reflected wave side configuration of each mirror is shown in drawing 4 on the wavelength of 13.4nm. The undulater light source which is a kind of the insertion light source of synchrotron orbital radiation was used for the light source 1. Based on this measurement result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0043] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0044] The example which applied example 3 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one

fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, it measured by the Foucault test as shows the reflected wave side configuration of each mirror to drawing 7 on the wavelength of 13.4nm. The discharge plasma light source was used for the light source 1. Based on this measurement result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0045] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0046] The example which applied example 4 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, it measured by the Ronchi test as shows the reflected wave side configuration of each mirror to drawing 9 on the wavelength of 13.4nm. The X-ray laser was used for the light source 1. Based on this measurement result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0047] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0048] The example which applied example 5 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, it measured by the Hartmann method the reflected wave side configuration of each mirror is shown in drawing 12 on the wavelength of 13.4nm. The laser plasma light source was used for the light source 1. Based on this measurement result, the contour map [like] showing an example in drawing 15 of each mirror was created.

Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0049] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0050] The example which applied example 6 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, having attached these mirrors in the interior of a lens-barrel, and measuring a transmitted wave side, it adjusted so that wave aberration might become min. Measurement of a transmitted wave side was performed with the shearing interference method as shown in drawing 3 on the wavelength of 13.4nm. The laser plasma light source was used for the light source for measurement. From the measured wave aberration, the amount of amendments of the reflector configuration of each mirror was computed using optical design software. Based on this result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0051] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0052] The example which applied example 7 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, having attached these mirrors in the interior of a lens-barrel, and measuring a transmitted wave side, it adjusted so that wave aberration might become min. Measurement of a transmitted wave side was performed by the PDI method as shown in drawing 5 on the wavelength of 13.4nm. The undulater light source which is a kind of the insertion light source of the synchrotron orbital radiation light source was used for the light source for measurement. From the measured wave aberration, the amount of amendments of the reflector configuration of each mirror was computed using optical design software. Based on this result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration

precision was able to be reduced to 0.15nmRMS(s).
[0053] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.
[0054] The example which applied example 8 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, having attached these mirrors in the interior of a lens-barrel, and measuring a transmitted wave side, it adjusted so that wave aberration might become min. The Foucault test as shown in drawing 8 on the wavelength of 13.4nm performed measurement of a transmitted wave side. The laser plasma light source was used for the light source for measurement. From the measured wave aberration, the amount of amendments of the reflector configuration of each mirror was computed using optical design software. Based on this result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).
[0055] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.
[0056] The example which applied example 9 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, having attached these mirrors in the interior of a lens-barrel, and measuring a transmitted wave side, it adjusted so that wave aberration might become min. The Ronchi test as shown in drawing 10 on the wavelength of 13.4nm performed measurement of a transmitted wave side. The discharge plasma light source was used for the light source for measurement. From the measured wave aberration, the amount of amendments of the reflector configuration of each mirror was computed using optical design software. Based on this result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).
[0057] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured

projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable.

[0058] The example which applied example 10 this invention to the projection optics of an EUV aligner is explained. Projection optics consists of six aspheric surface mirrors, numerical aperture (NA) has 0.25 by one fourth, and the scale factor has the ring field-like exposure field. First, each aspheric surface mirror was manufactured with the conventional polish processing technique. The configuration precision of each mirror was 0.5nmRMS(s). The wave aberration which assembles these and is obtained is 2.4nmRMS(s). Since it is necessary to hold down wave aberration to below 1nmRMS extent in order to use it on the wavelength of 13.4nm, the configuration precision of a mirror is insufficient as [this]. Next, Mo/Si multilayers were formed in the reflector of each aspheric surface mirror. First, the 50-layer laminating of the multilayers of 6.8nm of cycle length was carried out. Multilayers formed membranes by ion beam sputtering. Next, having attached these mirrors in the interior of a lens-barrel, and measuring a transmitted wave side, it adjusted so that wave aberration might become min. Measurement of a transmitted wave side was performed by the Hartmann method as shown in drawing 13 on the wavelength of 13.4nm. The X-ray laser was used for the light source for measurement. From the measured wave aberration, the amount of amendments of the reflector configuration of each mirror was computed using optical design software. Based on this result, the contour map [like] showing an example in drawing 15 of each mirror was created. Spacing of a contour line was set to 0.2nm equal to the amount of amendments of the reflector configuration when opposite-removing multilayers further. The front face of **** with a radical and multilayers was further removed every to this contour map, and the reflected wave side was amended. When each mirror was amended, configuration precision was able to be reduced to 0.15nmRMS(s).

[0059] Wave aberration was able to be set to 0.8nmRMS(s), when it adjusted so that these mirrors might be incorporated in a lens-barrel device and wave aberration might become min. This is sufficient value in order to obtain the image formation engine performance of a diffraction limitation. Thus, the manufactured projection optics was included in the EUV aligner, and the exposure test was performed. Even the detailed pattern of 30 nmL&S was resolvable. In addition, the conceptual diagram of the aligner using the soft-X-ray optical system of this invention and it was described in drawing 16 . The inside IR1-IR4 of drawing is the reflecting mirror of an illumination system, and PR1-PR4 are the reflecting mirrors of a projection system.

[0060]

[Effect of the Invention] Since unit quantity of amendment can be made smaller than before in the approach of removing the front face of multilayers every further and amending a reflected wave side configuration as mentioned above according to this invention, the wave-front amendment with a more high precision can be attained, can reduce the wave aberration of optical system, and can improve an image formation property.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] The plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror with a shearing interferometer.

[Drawing 2] Drawing explaining the principle of the reflected wave side phase correction by surface removal of multilayers.

[Drawing 3] The plot plan which measures the transmitted wave side of soft-X-ray optical system with a shearing interferometer.

[Drawing 4] The plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by PDI.

[Drawing 5] The plot plan which measures the transmitted wave side of soft-X-ray optical system by PDI.

[Drawing 6] Drawing of a PDI plate.

[Drawing 7] The plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by the Foucault test.

[Drawing 8] The plot plan which measures the transmitted wave side of soft-X-ray optical system by the Foucault test.

[Drawing 9] The plot plan which measures the reflected wave side configuration of a multilayers reflecting

mirror by the Ronchi test.

[Drawing 10] The plot plan which measures the transmitted wave side of soft-X-ray optical system by the Ronchi test.

[Drawing 11] Drawing of the grid used for the Ronchi test.

[Drawing 12] The plot plan which measures the reflected wave side configuration of a multilayers reflecting mirror by the Hartmann method.

[Drawing 13] The plot plan which measures the transmitted wave side of soft-X-ray optical system by the Hartmann method.

[Drawing 14] Drawing of the plate used for the Hartmann method.

[Drawing 15] Drawing explaining the procedure which computes the amount of amendments from the measured value of a reflector configuration.

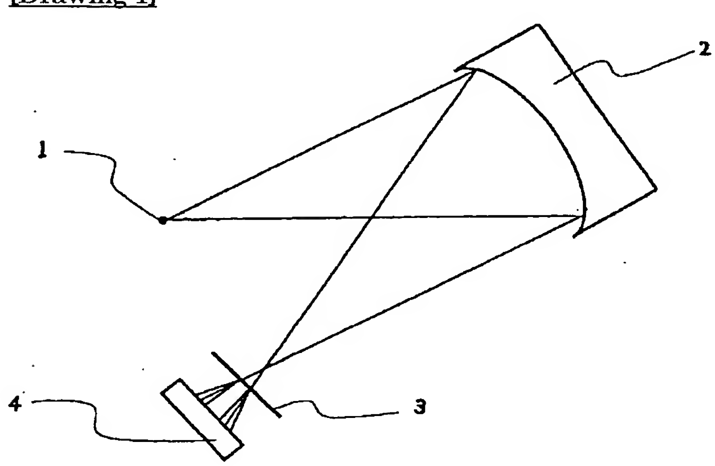
[Drawing 16] The aligner which has the optical system of suitable soft X ray to apply the invention in this application.

[Description of Notations]

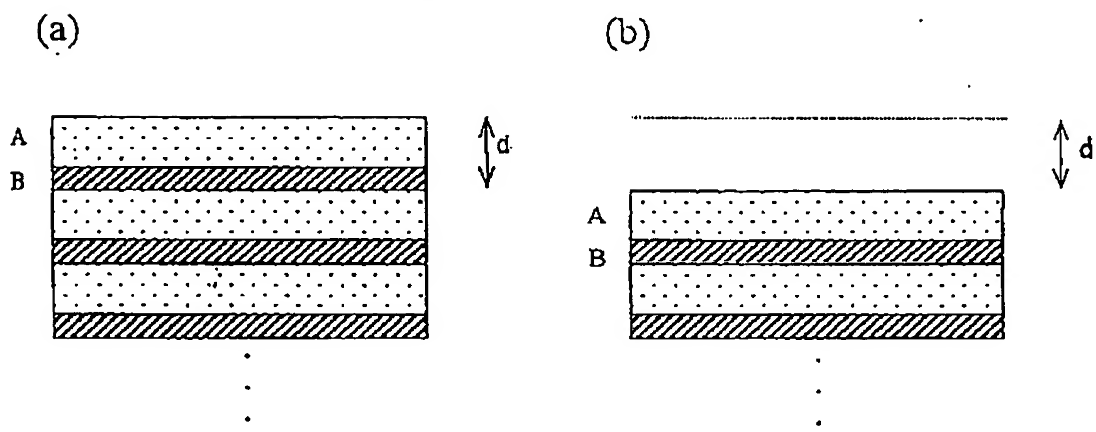
1 ... Light source
2 ... Multilayers reflecting mirror
20 ... Soft-X-ray optical system
3 ... Transmission grating
4 ... Image detector
5 ... PDI plate
51 ... Opening
52 ... Pinhole
6 ... Knife edge
7 ... Grid for the Ronchi tests
71 ... Opening
8 ... Plate for the Hartmann methods
81 ... Opening
L ... Laser for plasma excitation
S ... Source of luminescence
C ... Capacitor Mirror
IR1-IR4 ... Reflecting mirror of an illumination system
IP1-IP4 ... Reflecting mirror of a projection system
M ... Mask (reticle)
W ... Wafer

DRAWINGS

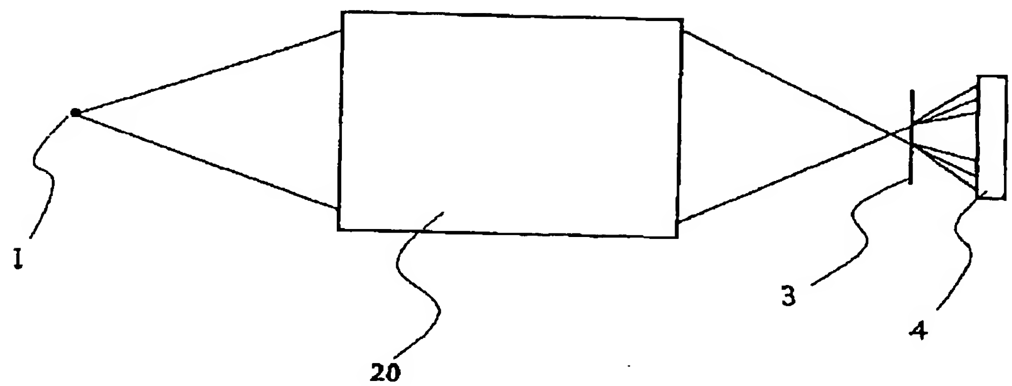
[Drawing 1]



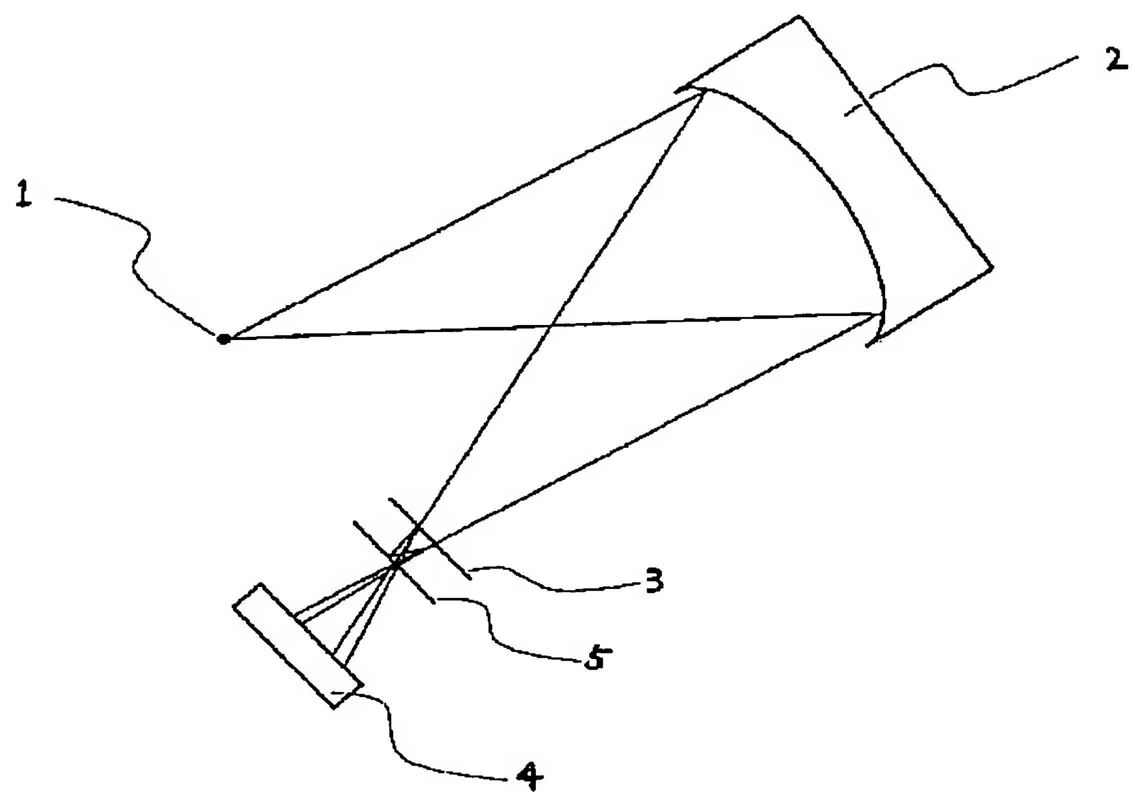
[Drawing 2]



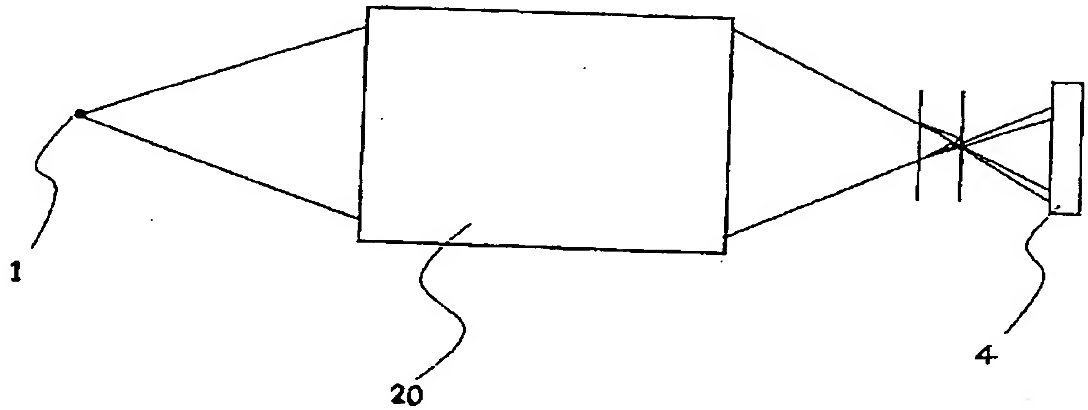
[Drawing 3]



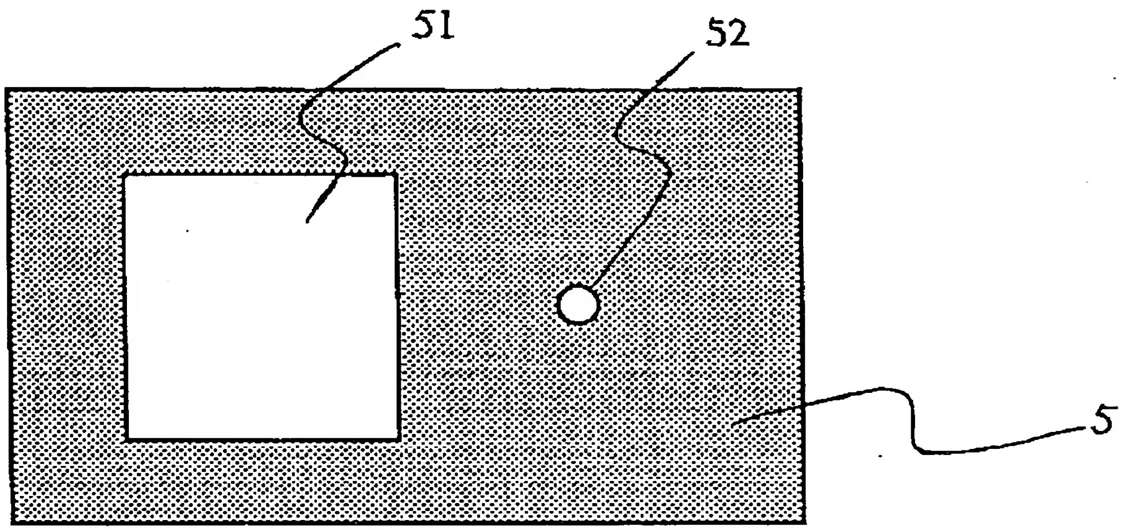
[Drawing 4]



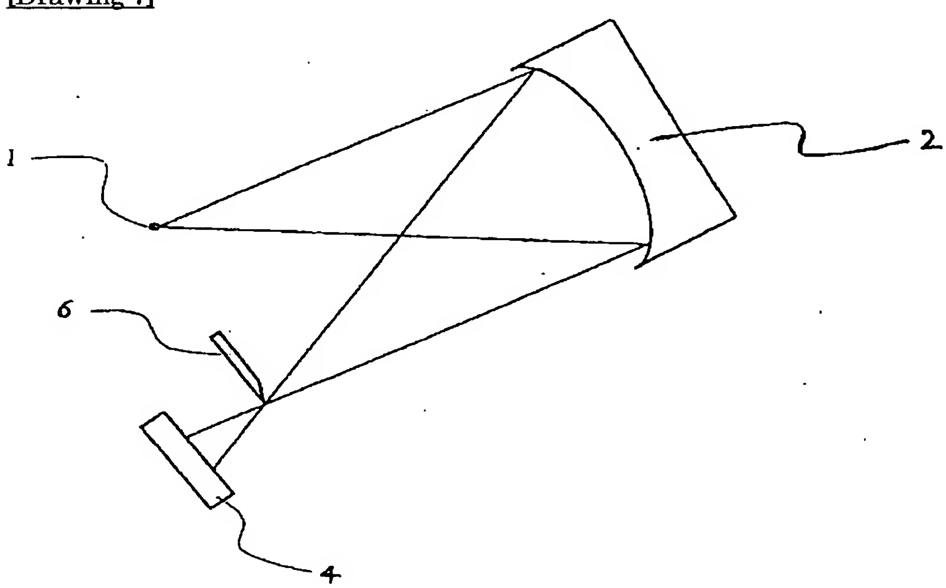
[Drawing 5]



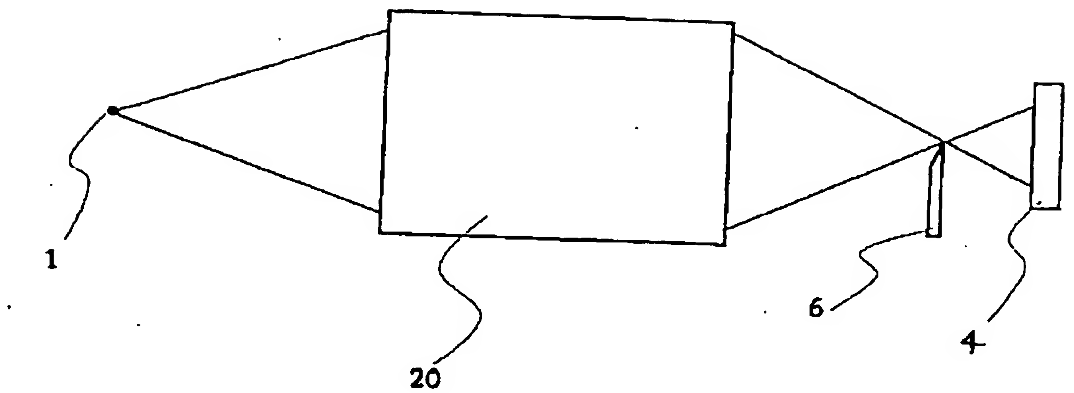
[Drawing 6]



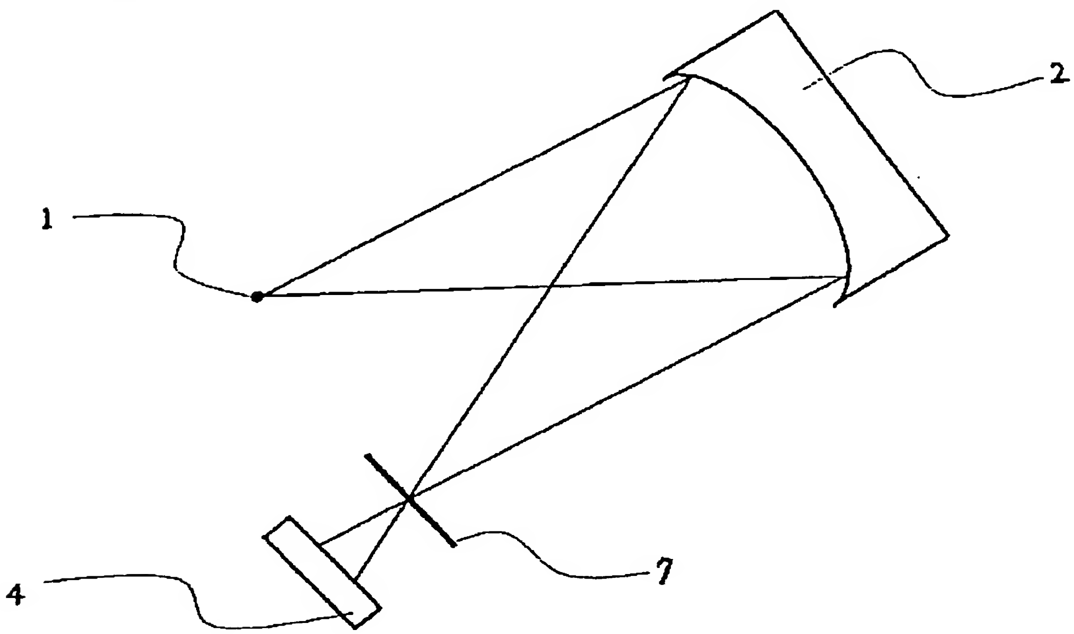
[Drawing 7]



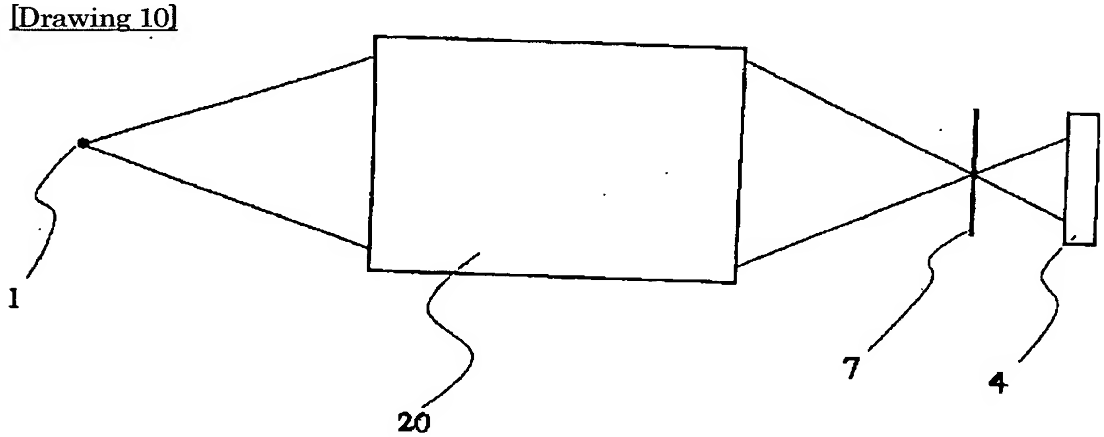
[Drawing 8]



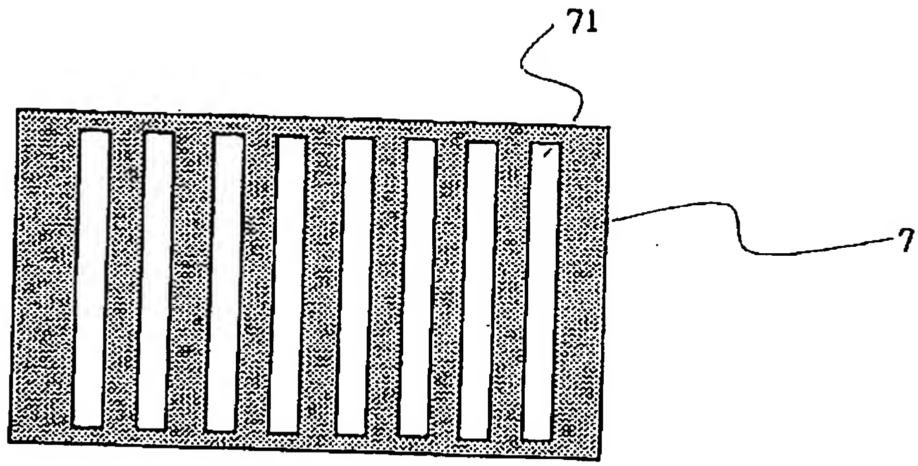
[Drawing 9]



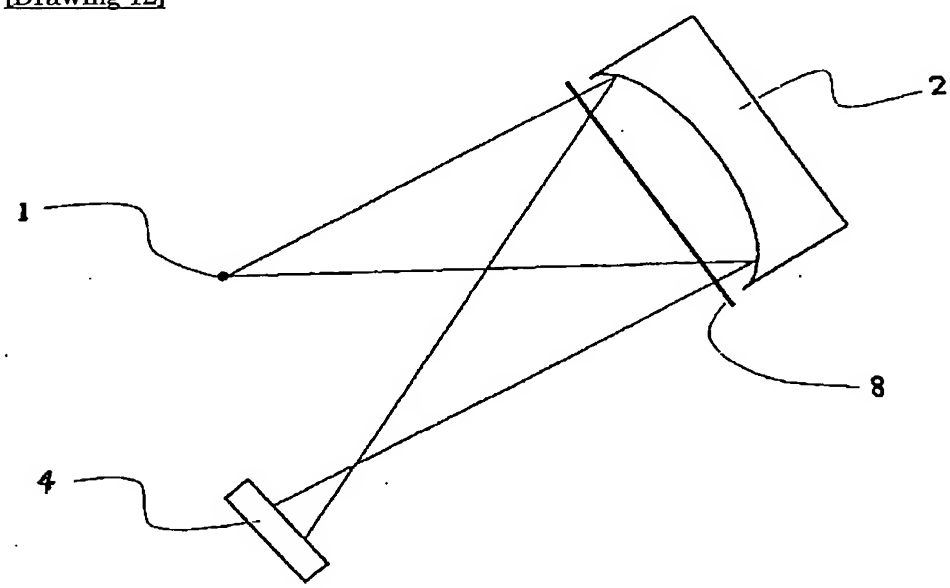
[Drawing 10]



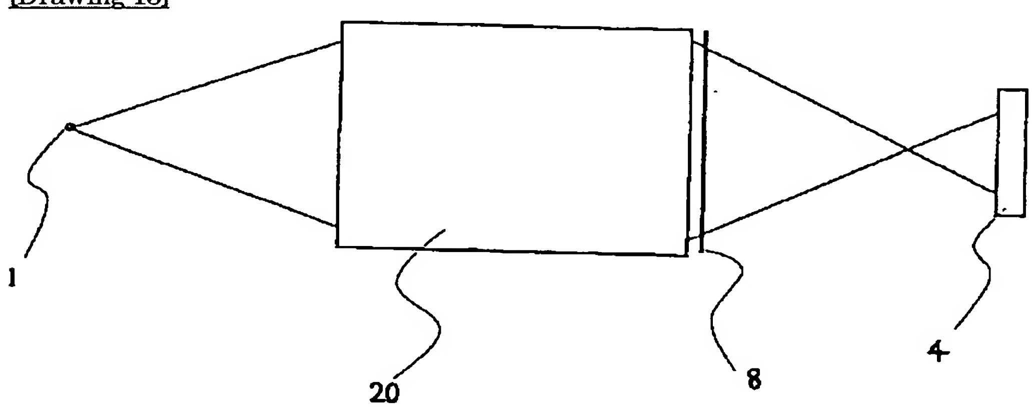
[Drawing 11]



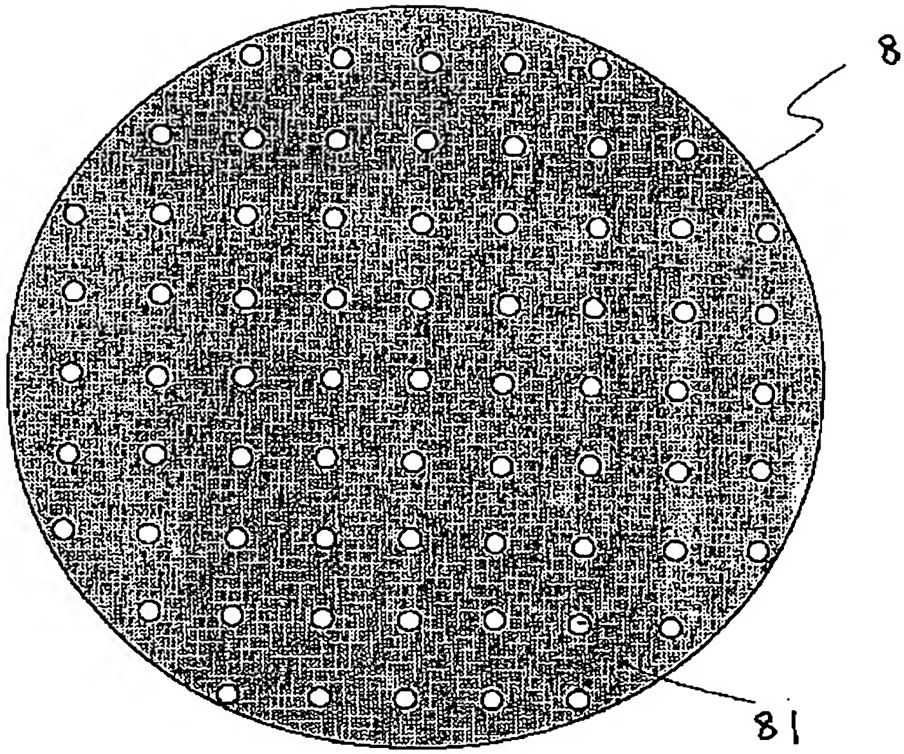
[Drawing 12]



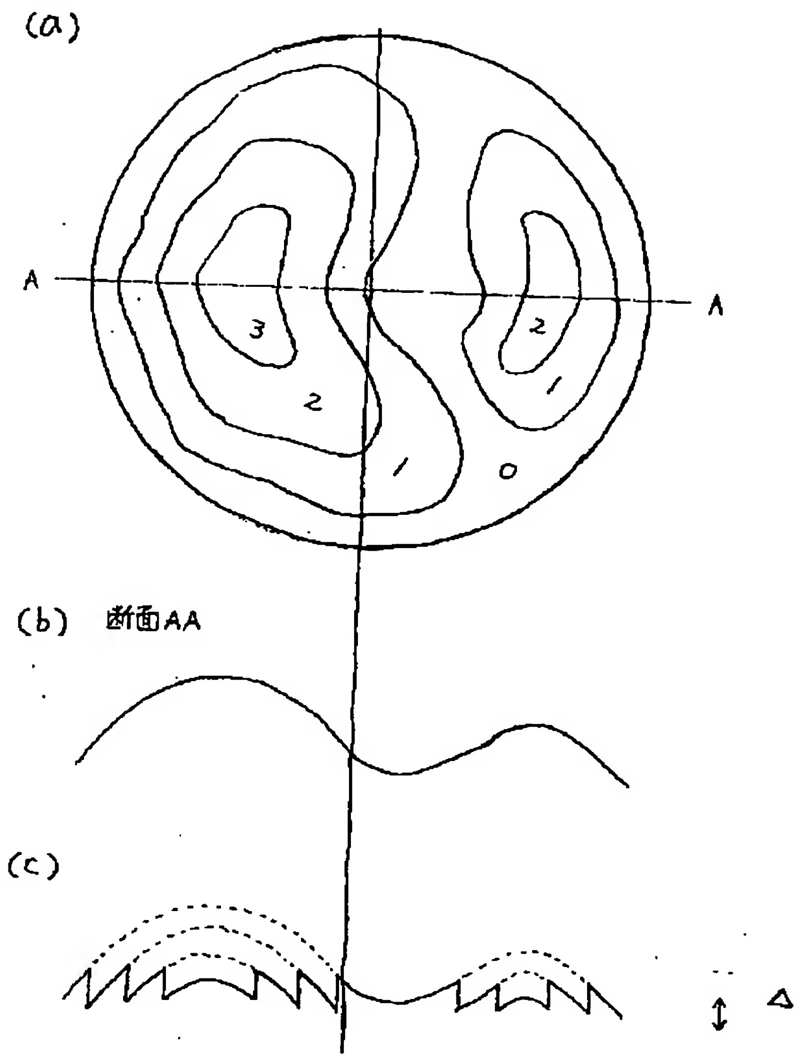
[Drawing 13]



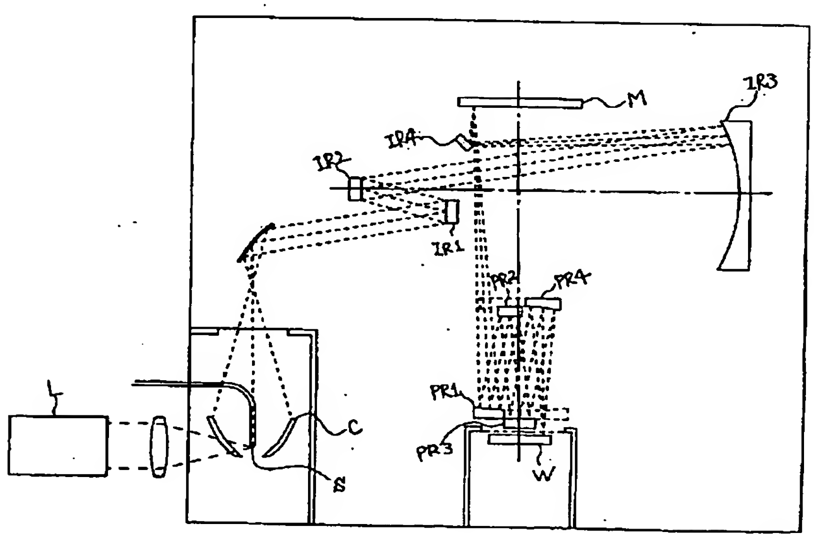
[Drawing 14]



[Drawing 15]



[Drawing 16]



[Translation done.]